

METAL-SILICATE PARTITIONING OF K AS A FUNCTION OF COMPOSITION AND TEMPERATURE: TESTING ITS FEASIBILITY AS A HEAT PRODUCING ELEMENT IN PLANETARY CORES N. Agmon¹, E. S. Steenstra¹, G. L. Arntz¹, Y. H. Lin¹, S. Matveev², J. Berndt³, S. M. Luginbühl¹, N. Rai⁴, S. Klemme³, W. van Westrenen¹ ¹Faculty of Earth & Life Sciences, Vrije Universiteit Amsterdam, NL (e.s.steenstra@vu.nl), ²Dept of Petrology, Utrecht University, Utrecht, NL ³Dept of Mineralogy, University of Münster, Germany ⁴Indian Institute of Technology Roorkee, India

Introduction: ⁴⁰K has been proposed as a possible heat producing element in planetary cores [1-3]. Heat from ⁴⁰K decay could affect the thermal evolution of planetary interiors, the evolution and onset of a core dynamo and the timing and nature of inner core crystallization [3-4]. The variables that affect the metal-silicate partition coefficient (D) of K are not well constrained, and therefore it is unclear to which extent K resides in planetary cores. For example, some studies suggest that silicate melt composition profoundly affects the metal-silicate partition coefficient (D) of K, whereas other studies suggest significant temperature (T) effects [3,5]. Pre-2003 experimental studies used oil- or water-based polishing techniques, which has been proven to preferentially remove K from the metal during polishing [3], prohibiting adequate comparison between many datasets. Recent geochemical models of core formation in the Moon, Mars, Mercury, Earth and asteroids [e.g. 6-13] have provided new constraints on plausible metal compositions and temperatures (T) during core formation. To reassess the role of K as a major heat producing element in planetary cores, we present new $D(K)$ values as a function of T and composition.

Approach: We performed experiments at 1 GPa and between 1683–1883 K using Pt-C or MgO capsules. Capsules were loaded with synthetic equivalents of diopside, a lunar granite or A15C lunar green glass, to study possible effects of silicate melt composition on $D(K)$. Metals consisted of Fe, FeC, FeCSi or FeS alloys, to constrain the effects of metal composition on $D(K)$. Run times varied between 15-120 min. As K is highly soluble in oil-water based liquids [3], samples were dry polished. Potassium abundances were quantified using LA-ICP-MS and EPMA.

Results: Run products consisted of well segregated metallic blobs within a homogeneous quenched glass (Fig. 1). In agreement with previous work, we observed that K is heterogeneously distributed in the metal [3]. We find that there is in general good agreement between LA-ICP-MS and EMPA measurements of K abundances (Fig. 2). No significant K loss was observed relative to the starting compositions and a time series confirmed equilibrium is attained within <15 min at 1683 K.

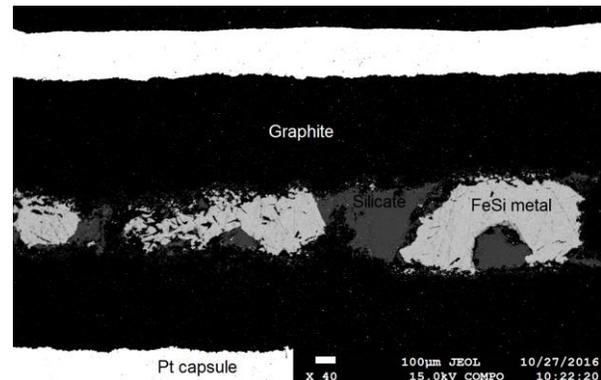


Fig. 1: BSE image of typical run product

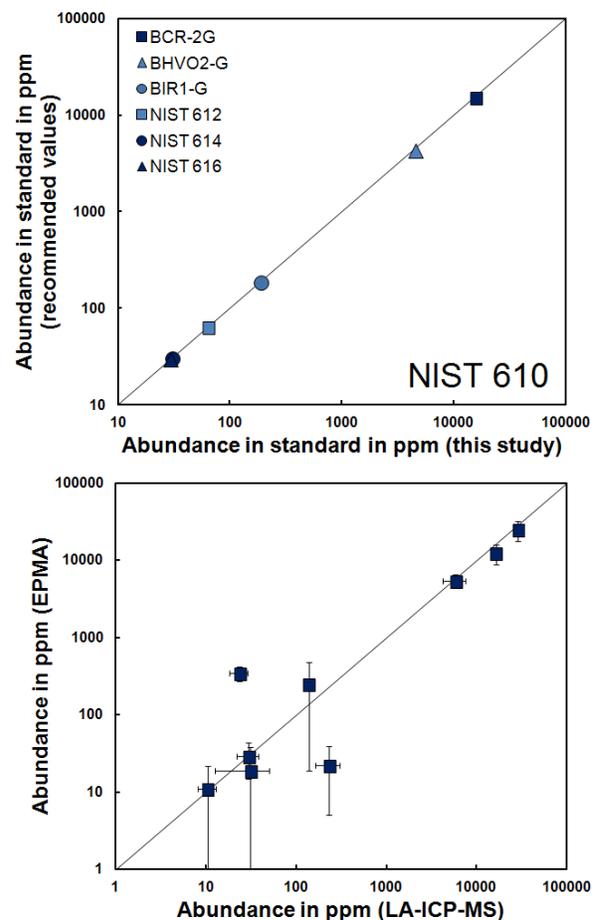


Fig. 2: Comparison between measured and reported K concentrations in different reference materials (top) and comparison between K in metal measured by LA-ICP-MS and EPMA. Lines are 1:1 identity lines.

Metal composition: Addition of S significantly increases the solubility of K in liquid metal and this dependence is well quantified (Fig. 3). This is in agreement with [3,5], but does not agree with [14], who suggest that dissolved O solely enhances D(K). We find that Si dissolved in the metal results in a decrease of D(K) (Fig. 3).

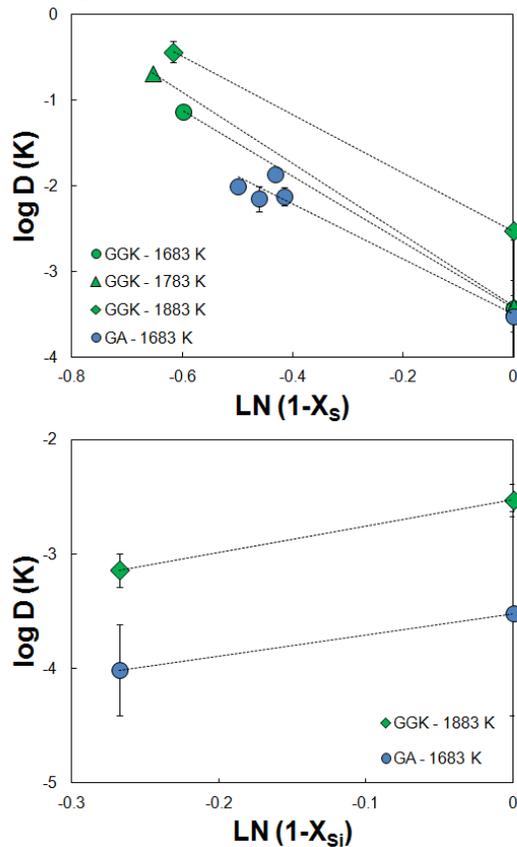


Fig. 3. Effect of S (top) and Si in metal (below) on D(K) at constant P, T and silicate melt composition. GGK and GA denote different silicate melt compositions.

Temperature: At similar composition and constant P, we find a clear and significant increase of D(K) with T, even within the relatively limited range of 1683-1883 K of this study (Fig. 4). This is again consistent with most previous work [3,5,16], but not with [14]. Note that [5,14] relate this T effect due to dissolved O in the metal, which in turn would enhance D(K). If T dependencies on D(K) are the result of enhanced solubility of O, this would imply T dependencies on D(K) obtained for FeS liquids potentially cannot be used to predict the T dependence of D(K) in other metal alloys, as the solubility of O in these alloys may be different. However, Rubie et al. [17] found that O solubility in FeNi alloys are not significantly affected by addition of up to 30 wt% S. This is supported by the similar T de-

pendencies of D(K) for Fe and FeS systems reported by [16] from a compilation of several D(K) datasets. The D(K) values of our GGK series with coexisting FeSi metal also suggest an increase with T.

Silicate composition: At identical P-T and similar metal composition, there seems to be a significant increase of D(K) with *nbo/t*. This would be in agreement with the observations of [5,15], but opposite to that observed by [3], who suggest a significant decrease. Bouhifd et al. [16] reported no effects of *nbo/t* on D(K) from *nbo/t* = $>0.8 \pm 0.4$ to 3.1, though only one experiment was performed at *nbo/t* = 3.1. Our initial results seem to suggest that D(K) increases linearly with *nbo/t*. This has to be confirmed by additional experiments, which will be reported at the meeting.

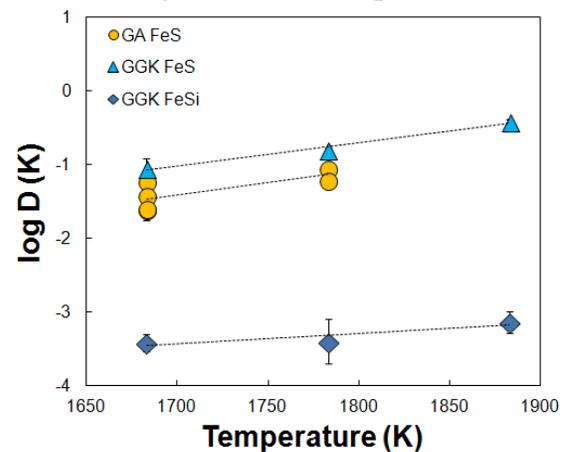


Fig. 4. D(K) as a function T. Values are normalized to common FeS value according to trends shown in Fig. 3.

Conclusions: We show that at conditions relevant for planetary differentiation (high *nbo/t* and high T) the role of ^{40}K as a heat producing element may be significant, even in the absence of a FeS-rich core.

References: [1] Lewis (1971) *EPSL* 11, 130 [2] Hall & Murthy (1971) *EPSL* 11, 239-244 [3] Murthy et al (2003) *Nature* 423, 163 [4] Williams & Nimmo (2004) *Geology* 32(2), 97 [5] Gessman & Wood (2002) *EPSL* 200, 63 [6] Rai & van Westrenen (2013) *JGR* 118, 1195 [7] Rai & van Westrenen (2014) *EPSL* 388, 343 [8] Steenstra et al (2016) *EPSL* 441, 1 [9] Steenstra et al (2016) *GCA* 177, 48 [10] Steenstra et al (2017) *AM*, in press [11] Righter et al (2015) *MAPS* 50, 604 [12] Chabot et al (2014) *EPSL* 390, 199 [13] Wade & Wood (2005) *EPSL* 236, 78 [14] Corgne et al (2007) *EPSL* 256, 567 [15] Chabot and Drake (1999) *EPSL* 172, 323 [16] Bouhifd et al (2007) *PEPI* 160, 22 [17] Rubie et al (2004) *Nature* 429, 58